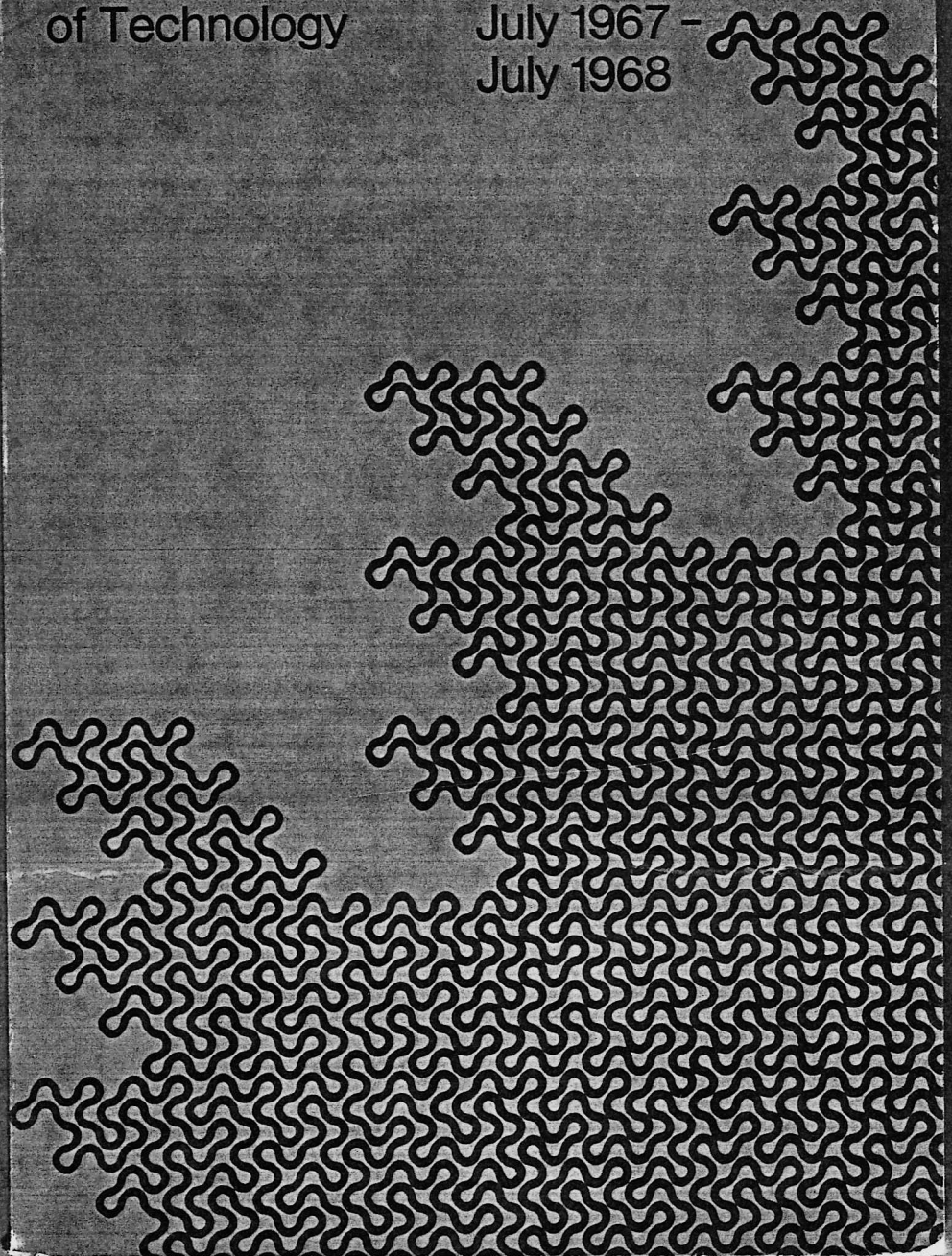


Massachusetts
Institute
of Technology

Project MAC
Progress Report V
July 1967 -
July 1968



NBS 453/10

[Editor's Note: The personnel of this section are a subset of participants from the Electronics Systems Laboratory, and therefore are included in that section's List of Personnel.]

Display Systems Research - John E. Ward

The ESL Display Group has been performing research and development in the field of computer-driven CRT displays and related equipment for several years in support of the ESL Computer-Aided Design Project and of Project MAC at M.I.T. During this time, the group has developed a number of hardware devices, including: the ESL Display Console, which is now connected to the Project MAC 7094 time-sharing system via a PDP-7 buffer computer; a scan-conversion system, to convert computer displays to TV format; and a low-cost remote graphic terminal for time-shared computer systems. The following paragraphs describe progress during the past year in improving these systems, developing graphics system software, developing techniques for terminal and inter-computer communications, developing hard-copy techniques, and planning future display applications for the Project MAC Multics (GE 645) system. (Also, see Kaplow, this volume.)

A. ESL DISPLAY CONSOLE

Previous annual progress reports have discussed the design and construction of a special hardware interface that would permit a PDP-7 computer to be used as a buffer for the ESL Display Console, which formerly was operated directly from a direct data channel of the Project MAC 7094 time-sharing system. To expedite installation of the buffer system, and maintain software compatibility for existing users of the ESL Display Console, the interface was designed to splice the PDP-7 into the data channel connection in such a way that 7094 would act as if it was still "talking" to the display, and the display act as if it was still "talking" to the 7094. The first phase of the system software for this configuration, described in a later section, consisted of moving the display buffer memory and the associated real-time control programs from the 7094 supervisor to the PDP-7, retaining the same software interface for the user programs in the 7094.

The above system became fully operational in September 1967. The immediate benefits were a greatly reduced demand on CTSS time for display operations, a doubling of the amount of memory space available for user display lists, and elimination of the display "blackouts" which had previously occurred during 7094 drum swaps. The PDP-7 has also provided a valuable paper-tape input facility for Project TIP and Project Intrex, whose extensive data bases are primarily prepared on off-line paper-tape equipment. In addition, the PDP-7 tape reader was modified to permit reading of TTS (Teletypesetter) tapes for the newspaper information-processing project.

During the previous year, a second ESL Display Console was acquired by the M.I.T. Computation Center (now the IPC) and operated briefly on a channel basis from their 7094 CTSS. During the present year, it was decided to move this console to the Electronic Systems Laboratory in Building 35, buffer it with a PDP-9 computer acquired by the ESL Computer-Aided Design Project, and tie the PDP-9 to the Project MAC CTSS via a high-speed (50 or 230.4 kbps) telephone link. Because the 7094 possessed no communications adapters for such data speeds, it was decided to enter the Project MAC 7094 through the PDP-7, which already had channel-to-channel communication with the 7094. The main purposes of this tie-in, shown in Figure 8, are to experiment with communication procedures for remote buffered displays, and to provide an interim display capability in the Electronic Systems Laboratory. However, the test configuration was planned with the future in mind. Since the PDP-7 and the PDP-9 are now equipped for telephone-line communication, both displays may later be operated directly from Multics or the IPC 360-67 when these central time-shared facilities become equipped with suitable high-speed communication adapters.

Present status of the second ESL Console is that the PDP-9 console interface hardware, designed by D. Vedder, has been constructed and checked out, and the Type 637 communications adapters for the PDP-7 and PDP-9 have been installed by the Digital Equipment Corporation. The Type 303 Data Sets and connecting telephone line were ordered from the New England Telephone Company, but have been held up by the recent telephone strike. It is hoped that the communications link can be installed in the near future so that tests may begin.

B. ARDS LOW-COST DISPLAY

The computer-buffered, refreshed displays discussed in the preceding section provide a dynamic graphics capability needed for certain types of problems, but the expense of such equipment precludes widespread installation. To provide the average time-sharing system user with a graphics capability requires a low-cost display device which can directly replace the existing teletype terminals. During the past three years, the Display Group has been developing a new type of display terminal, called the Advanced Remote Display Station (ARDS) console, to provide high-speed alphanumeric and full graphical (picture-drawing) capability over an ordinary voice-grade telephone line.

Previous annual reports have described the design and construction of prototype electronics for use with a direct-view storage tube. The advantage of such a storage tube for this application is that no local refresh memory is required, the character and line generators need operate only fast enough to keep up with the incoming data on the

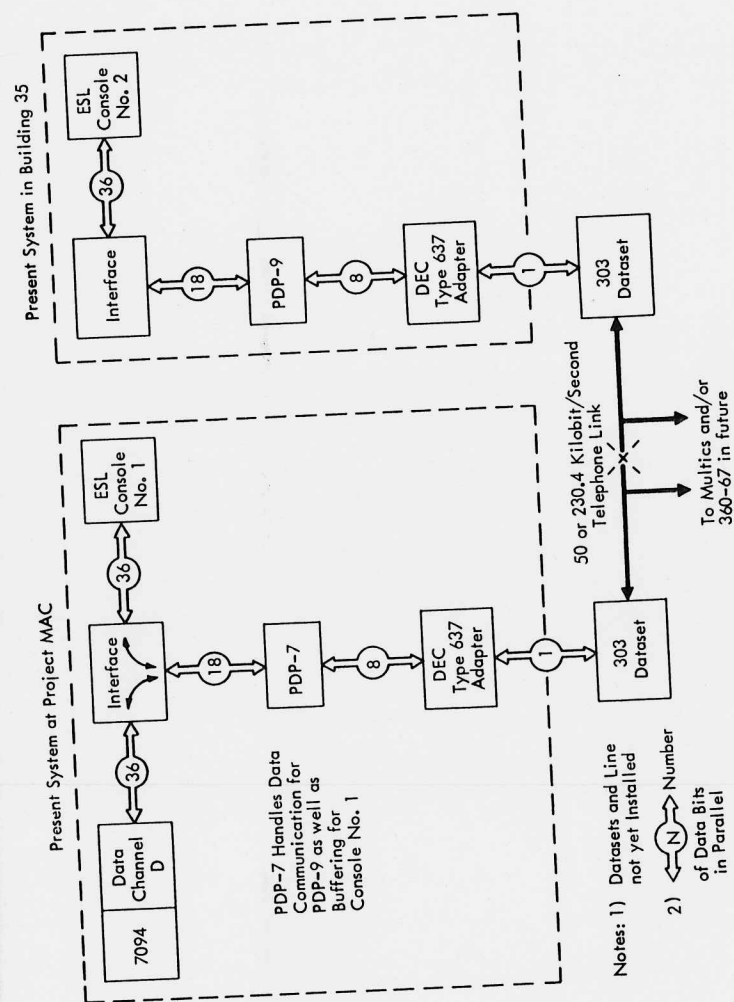


Figure 8. Data Link for Remote PDP-9/ESL Console System

telephone line, and more information can be displayed than on refreshed displays which are limited (by flicker considerations) in the amount they can display in one refresh cycle. The major remaining problem at the start of the present reporting year was that available storage tubes (five-inch) lacked adequate screen size and picture resolution. In August 1967, a new storage-tube monitor became available — the Tektronix Type 611. This new tube has a screen size of 6-1/2 x 8-1/2 inches and has a stored spot size of 0.008 inches. Incorporation of this new tube with the prototype electronics immediately resulted in an outstanding alphanumeric and graphical display capability, as shown in Figure 9.

The ARDS currently operates from CTSS over a switched telephone network at 1200 bit/sec (Type 202 Dataphone) which permits a character rate of 120 per second and a line-drawing rate of 30 to 60 per second. Over 4,000 characters may be displayed simultaneously on the screen, and pictures have no upper limit on the number of line components. For example, the global projection in Figure 9 (programmed by R. Gammill of the Meteorology Department) contains about 2,400 line components (drawing time 40 seconds), and serves as the base for weather displays in which isobars containing several thousand additional line components are added. (See Gammill, this volume.)

In March, 1968, R.H. Stotz and T.B. Cheek, principals in developing the ARDS, left the Display Group and formed a company to place the units on the market. Five units were immediately ordered by Project MAC and other M.I.T. groups for connection to CTSS. The first of these units was received in late June and is shown in Figure 10. The upper part of the table-top ARDS unit is a standard Tektronix Type 611 storage display monitor; the display electronics, Dataphone interface, and power supply are housed in the base section. In the first group of five ARDS, the keyboard is a separate self-contained unit manufactured by the INVAC Corporation. The small hemispherical device shown to the right of the display is a version of the Stanford Research Institute "mouse", a graphical input device which steers an electronically generated, non-storing cursor over the face of the screen. Buttons on the mouse permit transmission of x,y coordinates (or relative line coordinates) to the computer. Several graphical input programs have already been written. One of these permits the input of electrical circuits using the mouse to select elements from a "pick list" display on the screen.

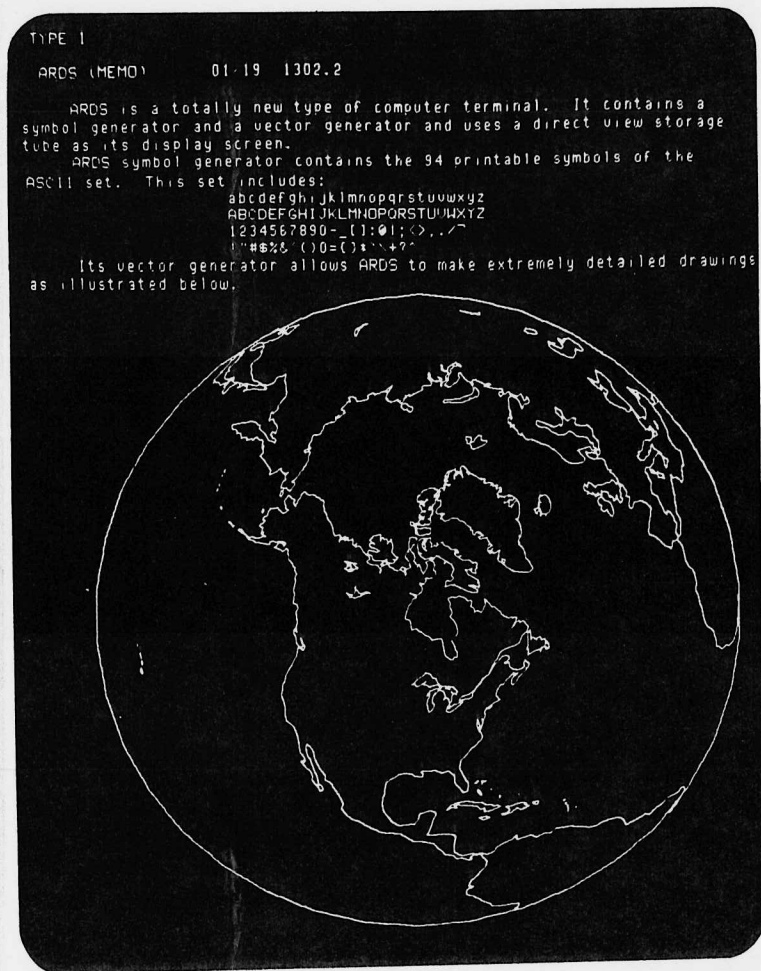


Figure 9. Sample ARDS Display

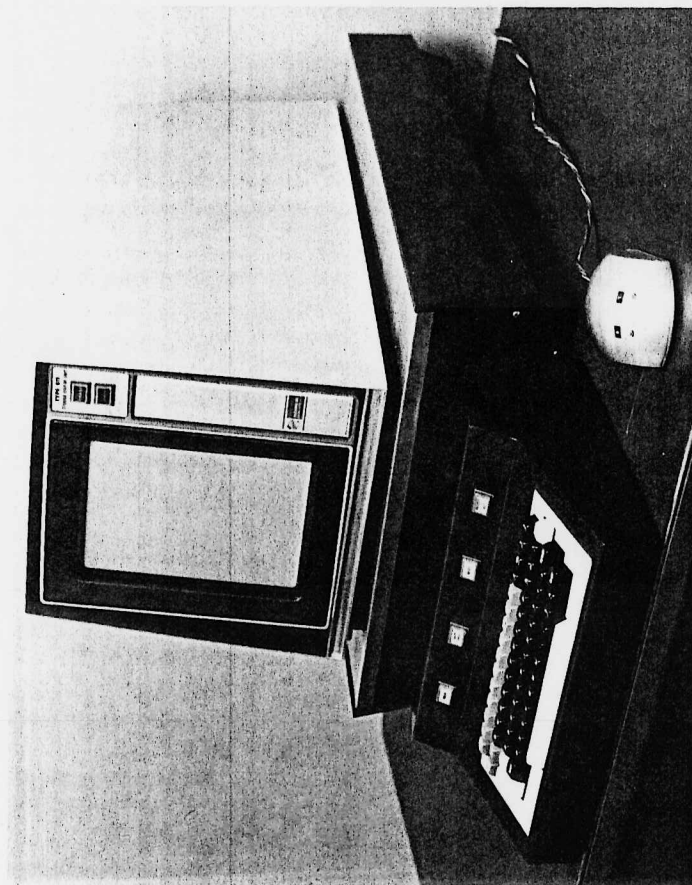


Figure 10. ARDS Display Terminal

At the close of the reporting period, preparations were being made for operation of the initial ARDS unit from West Berlin, Germany, in conjunction with the joint M.I.T.-Technical University of Berlin, Joint Summer Conference "Computers in the University", July 22 through August 3. A 1,200-bit link was being set up via a dial-up connection from West Berlin to Frankfurt, Germany; ITT Datel Service from Frankfurt to New York; and a dedicated AT&T line from New York to the Project MAC computer. As part of this effort, D. Vedder designed and constructed a hardware interface unit to permit ARDS to operate in a half-duplex mode when connected to the 7750 communications controller of the IBM 7094. This has now been established as a standard mode of operations for ARDS. [ARDS was successfully operated for an hour or more each day of the conference.]

M.I.T. Groups which have ordered or are actively considering ordering ARDS units include: Project MAC, the Materials Science and Engineering Center, the Civil Engineering Department, the M.I.T. Library (Project TIP), the Department of City and Regional Planning, the Center for International Studies, and the Sloan School of Management.

C. COMPUTER-TO-COMPUTER COMMUNICATION

With the tie-in of the remote computer-buffered ESL Console discussed in the first section, it became clear that attention should be given to the general problem of computer-to-computer communication. In particular, the establishment of standard character codes, message formats, and communications protocol would do much to improve the present situation, wherein the majority of existing inter-computer communication links have been tailored to meet the idiosyncrasies of I/O devices on individual machines, with no compatibility from one link to another.

A proposed set of standards has been developed, which was described in a MAC memorandum (see MAC-M-351, Appendix A) and in a paper by A.K. Bhushan and R.H. Stotz, presented at the 1968 Spring Joint Computer Conference. These standards, based on the USA Standard Code for Information Interchange (USASCII), permit transmission of binary data as well as text and incorporate the concept of a message header which can contain an address, message identification, and message description. Provision for message acknowledgement and error recovery are included. A.K. Bhushan became a representative on USASI Subcommittee X33 on Data Communications, which is studying these same problems.

The above standards relate to the form and content of messages on communications-type facilities, but say nothing about the facilities themselves. Consideration was also given to the types of links needed within the M.I.T. environment, and it was concluded that if all links (private wire or common carrier) are set up using common signaling standards, which are compatible with the existing common carrier communication facilities, then considerable flexibility can be achieved in communicating between different computers within M.I.T. and between these computers and other computers outside the M.I.T. environment. A set of standards and a "data switching center" was proposed in a Project MAC memorandum, "Recommendations for an Inter-Computer Communication Network for M.I.T." These standards are being used in the PDP-7/PDP-9 link. (See MAC-M-355, Appendix A.)

D. GRAPHIC SOFTWARE

1. Present Display Interface System

The initial programming of the Display Interface System for the buffered ESL Display Console was completed in September 1967. The PDP-7 buffer computer now stores the display file, maintains a picture on the console, performs real-time computations associated with control of the console hardware functions (rotation, translation, etc.), and processes display interrupts (light pen, push button, etc.) for users at two stations; functions which were previously performed by the IBM 7094 CTSS supervisor. This has freed approximately 2500 registers of core storage in the supervisor, and reduced the load on CTSS for driving the display from the previous 3 to 20 percent to a negligible level. Accounting routines have been written for the PDP-7 which enable us to measure the portions of the PDP-7 time employed in maintaining the picture. It was found that only about 3 to 30 percent of the PDP-7's time is used for this purpose, depending on how heavy the real-time action is.

The program packages and data flow between a user program in the 7094 and the display are shown in Figure 11. At the GRAPHSYS 1 (KLULIB) and A-core SDCOPE interfaces, the system looks to the user exactly like the former unbuffered system. The facilities available to the user in the PDP-7 console routines are the same as in the former 7094 routines and are fixed, since the user cannot change them. The main change in the 7094 is the new channel control program.

Also shown in Figure 11 is the data flow for the ARDS displays. The CTSS supervisor program WRFLX has been modified and a new program WSCOPE added to make the ARDS operate in the system very much like a teletype. Various hardware functions available on teletypes, but missing on the ARDS, are simulated by software. Initially, when the ARDS breadboard model had no keyboard or local echo capability, all input

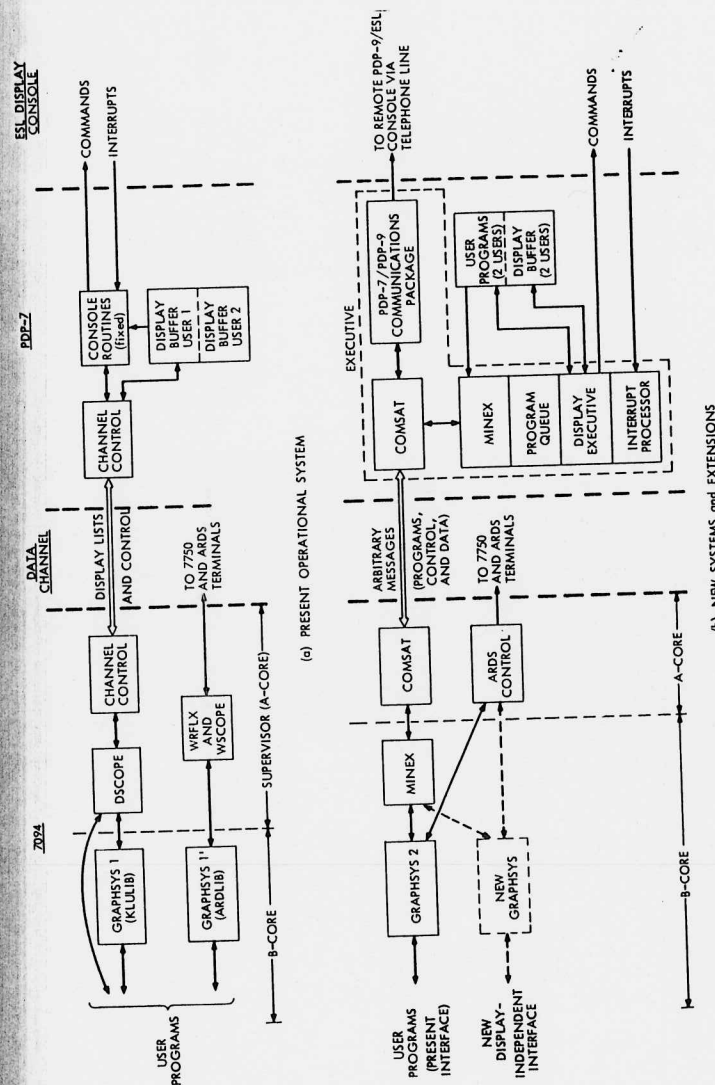


Figure 11. Present and Planned Display Interface Systems

characters were echoed by the CTSS supervisor. As the keyboard, hardware carriage return, and other features were added to the ARDS, the supervisor programs were modified accordingly. additional system programming was provided to handle "bottom-of-page wait" when a user's output reached the bottom of the screen and to allow the user to employ the full graphical drawing capability of the ARDS. When the graphical input devices were added to ARDS, supervisor programs were written to accept this new form of input.

The KLULIB programming system for the ESL Display Console was first modified about a year ago to provide a compatible programming interface to the ARDS, called ARDLIB. This package has been revised and extended during the past year by C. Reeve, in a Master's thesis research program, to add routines which allow the "mouse" graphical input device to be used like a light pen, and routines for defining "light buttons". Other software extensions include a display simulator package and provisions for storing ARDS pictures as CTSS disk files. Changes and additions are now being considered for GRAPHYSYS 1, so that the programming interfaces for ARDS and the ESL Console can be made as nearly identical as possible.

2. New Display Interface System

A major effort over the past year has been in the design of the next version of the Display Interface System, shown in Figure 11. The intent here is to provide a single interface for the ARDS and the ESL Console (and perhaps other graphic devices); reduce the supervisor portion of the software to the bare minimum communications functions; and, in the case of the PDP-7/ESL Console, permit users to write their own real-time display routines. To allow users maximum flexibility in allocating PDP-7 resources, the executive program in the PDP-7 consists of a minimal executive (MINEX) which interprets and handles all messages, handles storage allocation, and serves as the interface for user programs in the PDP-7. MINEX may be augmented at user request by standard programs for program queueing, display operation, interrupt processing, etc. The remainder of the memory space allocated to a user may be divided between user programs and display data in any way that the user wishes.

Design of the PDP-7 minimal executive, including a communications package for messages between the 7094 and the PDP-7 and an interrupt handler, has been completed by D.E. Thornhill and H.D. Levin. The augmented executive, including the program queue and general input/output handling routines, is being designed — as is in the display/program queue which will handle the interlock of display and real-time computations

on the display file. All of these programs permit two users at the two console stations to work independently. A first version of the COMSAT package for the 7094 has been written, and work is proceeding toward moving the present DSCOPE supervisor functions into B-core to form GRAPHYSYS 2. The general goal in this work, carried out in cooperation with the Computer-Aided Design Project, is to make the whole graphics software system as display independent and machine independent as possible. Toward this end, ideas are being collected for a new user interface, and attention is being given to the problems of moving the whole system to new computers, such as Multics and the S/360-67.

E. RELATED DISPLAY TECHNOLOGY

During the past year, a number of hardware investigations have been concerned with extensions of the present ARDS configuration.

In a Master's thesis research, J.R. Sussman designed and constructed a controller to incorporate a 1200 bit/second incremental magnetic tape recorder into the ARDS breadboard. All characters appearing on the telephone line, whether generated by the computer or the ARDS, are recorded. The controller supplies "page" numbering which is displayed on the ARDS screen, and can search on these numbers by means of commands typed on the ARDS keyboard. Thus the user may request redisplay of recorded pages on an off-line basis, providing a "look-back" capability similar to pulling back the paper on a teletypewriter to examine previously typed input/output. The recording system is also useful for off-line ARDS demonstrations. Further investigations of its use for off-line computer input are planned.

One of the difficulties with data-set-coupled terminal devices is that a delay of up to several weeks is usually incurred in getting the data set installed or moved to a new location. Acoustic and/or inductive couplers for ordinary telephone handsets are widely used for teletypewriter terminals (up to 300 bps), but no handset couplers for 1200 bps are commercially available. D. Chapman, in a Master's thesis research, designed a set of couplers which provide a full-duplex channel at 1200 bps in one direction and 150 bps in the other. Input at each end is acoustic, and pickup at each end is inductive. The ARDS breadboard was successfully operated for a two-week period using these couplers to establish a data circuit between two M.I.T. telephone extensions. Further refinement to fit the new ARDS half-duplex operating conventions is planned.

As discussed earlier, the ARDS terminal design was predicated on telephone-line coupling at data rates of 1200-2400 bits per second. At these data rates, the character and line generators (which operate at an incremental rate of 10 microseconds per point) have considerable dead time waiting for new instructions. In a Bachelor of Science thesis, R.G. Rausch investigated the improvement in display speed obtainable by removing the data-rate limitation and speeding up certain internal logic operations. By driving the ARDS data from the I/O bus of the PDP-7, he demonstrated a 4:1 improvement in drawing speed for characters and up to 8:1 for lines. Further logic changes to obtain an additional factor of 2:1 were worked out but not implemented. These results indicate additional uses for the ARDS as a direct-driven display, as well as growth potential as higher-speed data sets become available.

One of the problems with display-type terminals is that no hard-copy record is produced. A. Vezza is investigating a hard-copy technique in which a full-size photographic paper copy is made directly from the image on the face of the storage tube.¹ Using special wide-angle lenses and new dry-process (heat-developed) dry-silver emulsions which have recently come on the market, it is possible to obtain high-quality finished prints in 20 seconds — 10 seconds for exposure and 10 seconds for development. A prototype hard-copy station for the ARDS breadboard is now being designed and should be ready for trail use by late fall. Since such stations cost little more than an ARDS and operate over a telephone line in exactly the same way, they could be placed at various remote locations convenient to ARDS users.

INTERACTIVE MANAGEMENT SYSTEMS

SIMPLE Project

Marketing Models

Behavior of Complex Systems

Computer-Aided Diagnosis

A Branch and Bound Algorithm for Optimizing with a Simulation Model

Minimization of Machine-Dependent Routines

On-Line Data Analysis

APPENDIX A

PROJECT MAC MEMORANDA

<u>MEMORANDUM MAC-M-No.</u>	<u>SUBJECT</u>	<u>AUTHOR</u>	<u>DATE</u>
352	The BCPL Reference Manual	M. Richards	7/21/67
353	The Design and Programming of a Display Interface System Integrating Multi-Access and Satellite Computers (70429-M-190)	D. Ross R. Stotz D. Thornhill C. Lang	7/06/67
354	AED Flash 40: The Top-Down Mouse (APRAL) (70429-M-191)	I. Wenger	7/12/67
355	Recommendations for an Inter-Computer Communication Network for M.I.T.	A. Bhushan R. Stotz J. Ward	7/21/67
356	The ESL Display Console/PDP-7 System (70429-M-192)	D. Thornhill H. Levin R. Stotz	8/10/67
357	Decomposition of a Visual Scene into Bodies (AI No. 139)	A. Guzman	9/67
358	Perceptrons and Pattern Recognition (AI No. 140)	M. Minsky S. Papert	9/67
359	Revisions to the OPS-3 (CC 279)	R. Berman M. Jones W. Stuart	10/10/67
360	A Fast Parsing Scheme for Hand-Printed Mathematical Expressions (AI No. 145)	W. Martin	10/19/67

MEMORANDUM
MAC-M-No.

<u>SUBJECT</u>	<u>AUTHOR</u>	<u>DATE</u>
AED Flash 41: 7094-to-360 Conversion using AED (70429-M-194)	C. Feldmann	10/19/67
Techniques for the Digital Simulation of Complex Systems	J. Donovan	10/22/67
Direction for Updating the AED-0 Programmer's Guide, plus an Index of Terms, and a Description of AED-0 Items (70429-M-198-1)	D. Fulton D. Ross	1/16/68
How to Use BCPL on CTSS	M. Richards	2/14/68
AED Flash 42: Basic Input/Output Package (70429-M-199)	C. Feldmann D. Ross	3/07/68
Converting McCracken's Algol Book to Describe AED-0 (70429-M-200)	D. Ross D. Fulton	2/14/68
A Left-to-Right then Right-to-Left Parsing Algorithm (AI No. 155)	W. Martin	2/68
Graphic Output Performance of the ARDS Terminal with the Tektronix Type 611 Storage Display Unit	J. Ward	3/13/68
A Program for Drilling Students in Freshman Calculus Integration Problems	J. Moses	3/68

MEMORANDUM

MAC-M-No.	SUBJECT	AUTHOR	DATE
371	Numerical Solution of Elliptic Boundary Value Problems by Spline Functions	J. Shah	4/68
372	Some Considerations of Supervisor Program Design for Multiplexed Computer System	F. Corbato J. Saltzer	5/68
373	Running AED on the MIT 360 (70429-M-201)	C. Feldmann	5/02/68
374	Large Capacity Beam Addressable Memories	R. Kay	5/10/68
376	An Interactive Syntax Definition Facility	R. Eanes	6/17/68
377	ITS 1.4 Reference Manual	D. Eastlake	6/68
....REVISIONS....			
340-2	Telephone Extensions for Dataphones, Teletypes, and 1050's (CC 230-11)	M. Solomita	4/10/68
352-1	The BCPL Reference Manual	M. Richards	2/16/68
363-1	Direction for Updating the AED-0 Programmer's Guide, plus an Index of Terms, and a Description of AED-0 Items (70429-M-198-1)	D. Fulton D. Ross	2/19/68
366.1	Errata sheet to MAC-M-366	D. Ross D. Fulton	2/14/68
373.1	Addendum to MAC-M-373	C. Feldmann	5/27/68

APPENDIX B

M. I. T. THESES

Alsop, J. W., A Canonic Translator, Department of Electrical Engineering, B.S. Thesis, November 1967 (See also MAC-TR-46, Appendix D.)

Avrin, D. E., Computer Display of Protein Electron Density Functions, Department of Electrical Engineering, M.S. Thesis, August 1967

Banks, E. R., On the Simulation of Engineering Multiports, Department of Mechanical Engineering, M.S. Thesis, February 1968

Barkalow, T. J., Student Use of a Time-Sharing System, Department of Electrical Engineering, M.S. Thesis, August 1967

Beltran-Barragen, F., Scattering from Periodic Structures Related to the Insect Corneal Nipple Array, Department of Electrical Engineering, Ph.D. Thesis, February 1968

Chapman, D. G., Audio-Coupled Telephone Transmission of Medium-Speed Digital Data, Department of Electrical Engineering, M.S. Thesis, June 1968

Charniak, E., CARPS, A Program which Solves Calculus Word Problems, Department of Electrical Engineering, M.S. Thesis, June 1968 (See also MAC-TR-51, Appendix D.)

Clark, D. D., A Reductions Analysis System for Parsing PL/I, Department of Electrical Engineering, Ph.D. Thesis, June 1968

Davis, J. A., Computer Models of the Beam-Plasma Interaction, Department of Electrical Engineering, Ph.D. Thesis, June 1968

Denning, P. J., Resource Allocation in Multiprocess Computer Systems, Department of Electrical Engineering, Ph.D. Thesis, June 1968 (See also MAC-TR-50, Appendix D.)

Doyle, J. T., Issues of Undecidability in Canonic Systems, Department of Electrical Engineering, M.S. Thesis, February 1968

Geffner, S. L., Eye-Tracking Program, Department of Mathematics, M.S. Thesis, January 1968

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13. ABSTRACT The broad goal of Project MAC is experimental investigation of new ways in which on-line use of computers can aid people in their individual work, whether research, engineering design, management, or education. This is the fifth annual Progress Report summarizing the research carried out under the sponsorship of Project MAC. Details of this research may be found in the publications listed in the Appendices at the end of this report.		
14. KEY WORDS Computers Machine-aided cognition Multiple-access computers On-line computers Real-time computers Time-sharing Time-shared computers		

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